Appendix E
Drainage Trench

E-1. General

This appendix presents the design and analysis of drainage trenches. The design criteria and the example presented are taken from U.S. Army Engineer Waterways Experiment Station TM 3-424 (Appendix A).

E-2. Applicability

A drainage trench can be used to control underseepage where the top stratum is thin and the pervious foundation is relatively shallow so that the trench substantially penetrates the aquifer. Where the pervious foundation is deep, a drainage trench of moderate depth would attract only a small portion of the underseepage. The drainage trench method is known to be effective where the ratio of the thickness of the landside blanket, z_{bl} , to the depth of the pervious foundation, d, is greater than 25 percent. While only substantial penetration by the drainage trench provides significant landside relief, a trench with limited penetration may be used in conjunction with a landside blanket to contain seepage pressures.

E-3. Design Criteria

The design criteria and graphs are applicable only for homogeneous, isotropic pervious foundations having an impervious top stratum landward of the drainage trench. The distance from the source of seepage to the landside toe of the levee, S, to be used in the design may be estimated by a procedure outlined in Appendix B. Seepage into a drainage trench, Q_{st}, and the maximum head landside of the levee, h_∞ , where the blanket landside of the levee consists of impervious or relatively impervious soil, can be computed using the graphs presented in Figure E-1. The analysis and design procedure is as follows:

a. Where $k_h > k_v$ transform the in situ pervious stratum into a homogeneous, isotropic formation using k'_f and d' for k_f and d, respectively, as follows:

$$k'_f = \sqrt{k_h\ k_v} \tag{E-1}$$

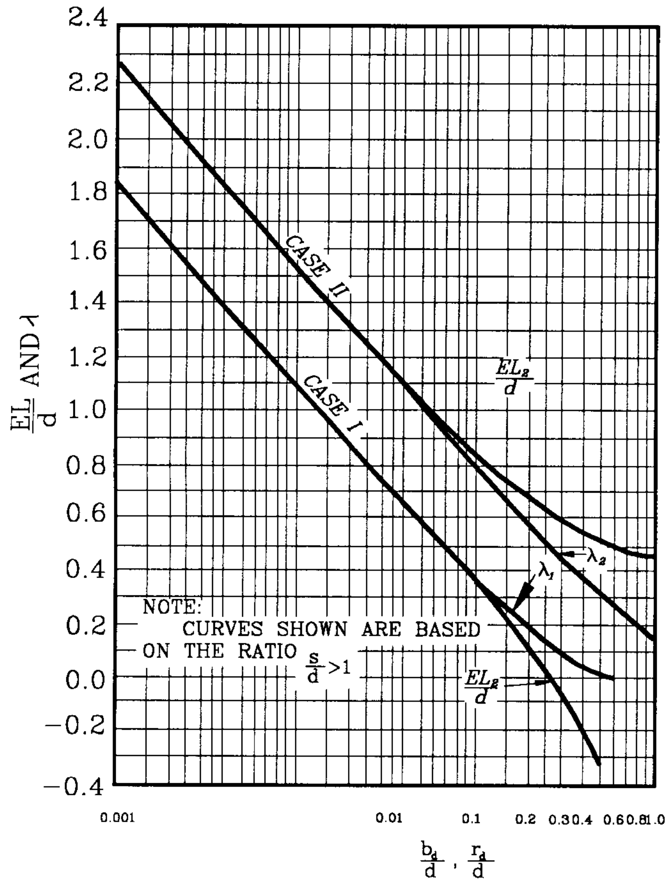
$$d' = d\sqrt{k_h/k_v} \tag{E-2}$$

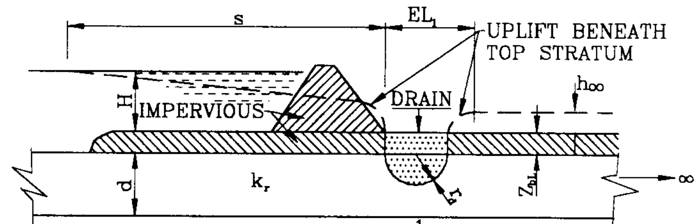
where

- d = thickness of the pervious foundation
- k_h = coefficient of horizontal permeability
- k_v = coefficient of vertical permeability
- k'_f = transformed coefficient of permeability of the foundation
- d' = transformed depth of the pervious foundation

b. From the geometry of the drainage trench, Figure E-1, find the ratio of r_d/d, (Case I) or b_d/d (Case II) where:

- r_b = radius of the circular sector of the trench for Case I
- b_d = width of the rectangular trench section for Case II

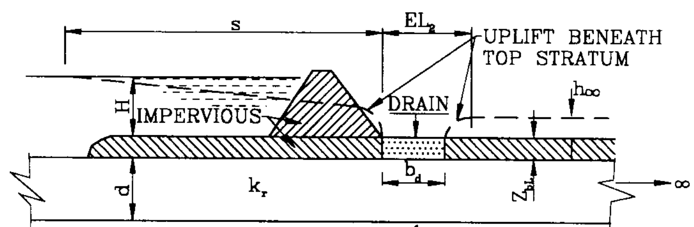




SHAPE FACTOR $\$ = \dfrac{1}{\dfrac{S+r_d}{d} + \dfrac{EL_1}{d}}$

MAXIMUM NET UPLIFT RATIO UNDER TOP IMPERVIOUS BLANKET LANDSIDE OF DRAIN IN $\dfrac{h_\infty}{H} = \$_1 \lambda_1$

CASE I



SHAPE FACTOR $\$ = \dfrac{1}{\dfrac{S}{d} + \dfrac{EL_2}{d}}$

MAXIMUM NET UPLIFT RATIO UNDER TOP IMPERVIOUS BLANKET LANDSIDE OF DRAIN IN $\dfrac{h_\infty}{H} = \$_2 \lambda_2$

CASE II

SEEPAGE PER UNIT LENGTH OF STRUCTURE IS A $Q = k_f H\$$

NOTE:
WHERE $K_H > K_v$, TRANSFORM PERVIUS SUBSTRATUM TO A HOMOGENEOUS, ISOTROPIC FOUNDATION AND USE $\bar{k}_f$ FOR k_f AND $\bar{d}$ FOR d IN ABOVE FORMAULAS.

$\bar{k}_f = \sqrt{k_h\ k_v}$ AND $\bar{d} = d\sqrt{\dfrac{k_H}{k_v}}$

Figure E-1. Formulas and design curves for drainage trenches (ref. EM 1110-2-1601)

c. Use the computed ratio of r_d/d or b_d/d to enter the appropriate graph of Figure E-1 to determine the corresponding value of EL/d and ë. The factor EL is the extra length of pervious substratums corresponding to the increased resistance to flow into a drainage trench as compared to a fully penetrated open trench, and ë is an uplift factor. The values of EL_1/d and ë, are related to Case I, while EL_2/d and $ë_2$ are related to Case II.

d. Once the magnitude of EL is determined, the value of the shape factor $\$$ which is equivalent to the ratio in the flow net of the number of flow channels to the number of equipotential drops, can be determined as:

Case I:

$$\$_1 = \frac{d}{S + r_d + EL_1} \tag{E-3}$$

Case II:

$$\$_2 = \frac{d}{S + EL_2} \tag{E-4}$$

e. Calculate the quantity of discharge per unit length of the levee, Q_{st}, and the maximum head landside of the trench, h_∞ , using the following expressions:

$$Q_{st} = \$ \, k'_f \, H \tag{E-5}$$

$$h_\infty = H \, \$ \, \text{ë} \tag{E-6}$$

where

H = total head acting on the levee, or the height of flood stage above the average low-ground surface or tail water

Where there is no top stratum landside of the levee, seepage flow into the drainage trench and beyond can be estimated from the flow net analysis.

E-4. Limitations of the Method

The method of controlling underseepage using the trench drain method has several limitations:

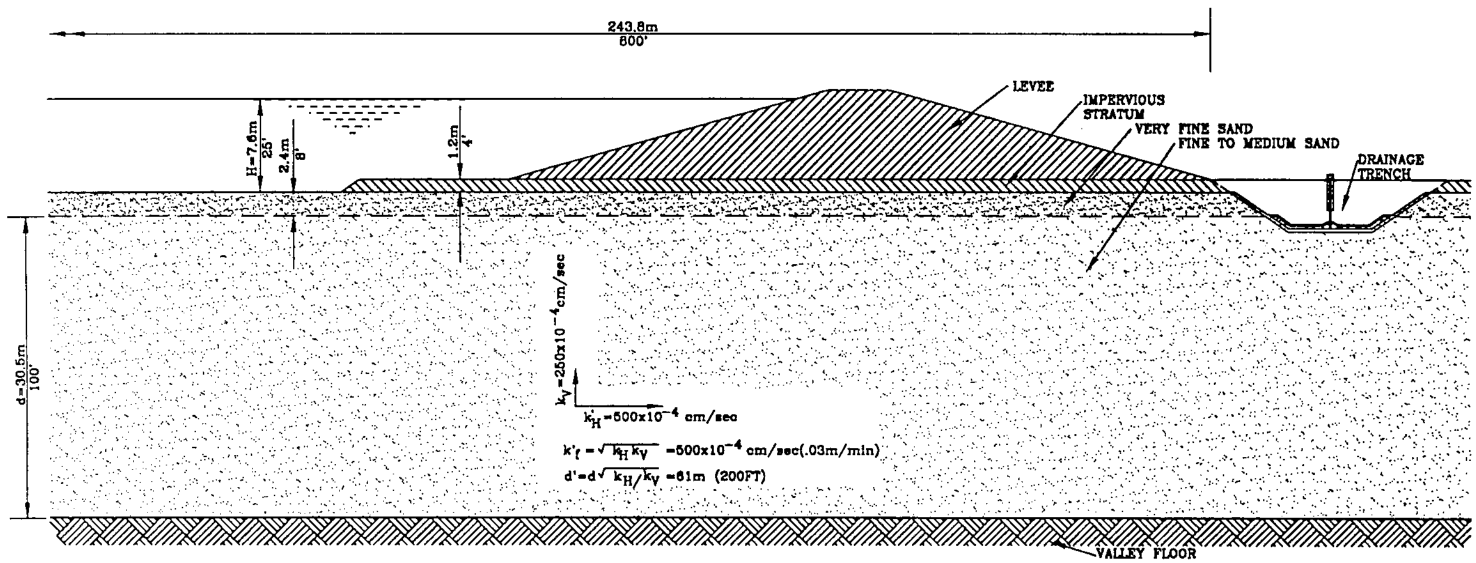
a. If the top stratum landside of the drainage trench has a certain degree of perviousness, seepage into the trench and the maximum head landward of the levee will be somewhat less than those computed from Figure E-1. Therefore, design based on Figure E-1 will be slightly on the conservative side if the top stratum landside of the drain trench is semipervious.

b. If the pervious foundation is highly stratified, seepage may bypass the drain and emerge landward of the drain thereby defeating its purpose. For such cases, other methods of seepage control are more effective.

c. If the trench is underlain by either impervious or semipervious strata of either clay, silt, or fine sand, the formulas presented in Part E-3 are no longer applicable.

E-5. Design Example

Figure E-2 illustrates the design of a drainage trench in a thin impervious blanket overlying a shallow pervious stratum. The trench drain (Case II) is designed using equations presented in Part E-3 of this appendix.



CROSS SECTION OF LEVEE, FOUNDATION AND DRAINAGE TRENCH

b_d/d =7.6m(25')/61m(200') =0.125 ; EL_2/d' =0.80 and λ_2 =0.75

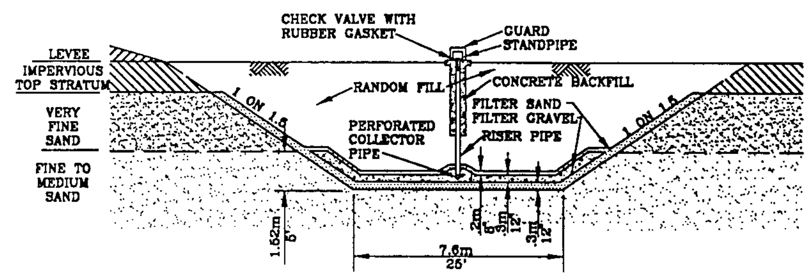
$$\mathcal{S} = \frac{1}{S/d' + EL_2/d'} = \frac{1}{243.8m(800')/61m(200')+0.8} = \frac{1}{4.8} = .208$$

SEEPAGE FLOW PER UNIT LENGTH OF LEVEE, Q_s:

$Q_s = \mathcal{S}\ k\,H$ = 0.208x.03m(.1')/min x 7.6m(25') =.0474m^3/mpm OF LEVEE
or 1.445m^{3}pm/30.5m(100') OF LEVEE

MAXIMUM HEAD BENEATH LANDSIDE BLANKET, h_∞ :

$h_\infty/H = \mathcal{S}$ .208x.75=.156 OR 15.6%
h_∞=1.56xH=.156x7.6m(25')= 1.17m(3.9')



DETAILS OF DRAINAGE TRENCH

Figure E-2. Example of design of a drainage trench